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Groundwater Quality Variations with Different Land Use Types in Belihul Oya Catchment.

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Abstract

Drainage basin characteristics, various land usage patterns with human interventions and seasonal differences in rainfall pattern, directly affect the water quality changes. Human interventions leading to land use changes may affect groundwater quality specially in agricultural areas. The objective of this study was examining the spatial variation of water quality changes in different types of land use in Belihuloya mini-catchment area. To investigate spatial variations of hydro-geochemical parameters, water samples were collected during North Eastern Monsoon (NEM) and 1st Inter Monsoon (1IM) season. Altogether, 20 water samples were selected containing 10 from springs, and 10 from the selected wells under recommended standards. The pH, and electrical conductivity (EC) were measured in the field using electrochemical methods. Titrimetric methods were used to determine the concentrations of chloride. HACH® digital titrator was used for all titrations. The anionic parameters Nitrate-N (NO3-–N), and sulphate (SO4-2), content were analysed using spectrophotometric methods. The cations, sodium (Na+), and calcium (Ca+2) were analysed using Atomic Absorption Spectrophotometric (AAS) methods (Perking Elmer- 2800). Finally, Inverse Distance weighting (IDW) method was used for contouring geochemical parameters in the study area using Arc GIS Ver.10.3. The study revealed that spatial variation of pH, and Ca in groundwater delineated several reasons behind water quality. However, spatial variation of NO3, SO4, Na, Cl, EC, and Ca, in groundwater have shown some variations parallel to land use categories. The well water showed a low pH levels than springs in the area. Spatial variation of Ca concentrations in water (Ca; 10.4-24 mg/l) in both spring and wells are higher along the down and middle catchment areas where predominantly Charnockitic is accumulated with limestone. According to the study, the groundwater quality variations have occurred due to variations of land use in the study area. Concentrations of most fertilizer driven parameters found in groundwater are higher along paddy lands, home gardens, tea and built-up areas, particularly in the middle catchment area where the earliest land use type was found as forests. The lower levels of above parameters in groundwater were observed along forests, scrubland, and grasslands. The use of high yielding varieties, chemical fertilization and the change in economic mode of production since 1956 have made considerable changes in the groundwater quality in the area.

Keywords: Groundwater, Water quality, land use, catchment areas.

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1. Introduction

The composition of surface and underground water is dependent on natural factors (geological, topographical, meteorological, hydrological and biological) in the drainage basin and it varies with seasonal differences in runoff volumes, weather conditions and water levels. Large natural variations in water quality may, therefore, be observed even where only a single watercourse is involved. Human intervention also has significant effects on water quality. Some of these effects are the result of hydrological changes, such as changing land use building of dams, draining of wetlands and diversion of flow. More obvious are the polluting activities, such as the discharge of domestic, industrial, urban and other wastewaters into the watercourse (whether intentional or accidental) and the spreading of chemicals on agricultural land in the drainage basin (Meybeck*et al,*1996).

Sri Lanka is blessed to have many natural resources including numerous water bodies. There are 103 natural river basins in Sri Lanka, with a total length of about 4,500km (UNESCO and MoAIMD 2008). In addition, there are a significant number of reservoirs including ancient irrigation reservoirs and recently constructed multi-purpose reservoirs with a total area of 169,941 hectares (MENR and UNEP 2009). Groundwater resources in the country are estimated at about 7,800 million m3 per year. Groundwater is the major source of water especially in rural areas, and it is estimated that about 72% of the rural population relies on groundwater for domestic use (Nandalal 2010).

In explaining the water quality around the country, it is difficult to comprehend the trend of water quality in public water bodies due to lack of monitoring data. However, the Sri Lanka National Water Development Report (2006) pointed out a variety of quality concerns in Sri Lanka, including contamination by nitrate and bacteria in underground and surface waters mainly due to poor sanitation and untreated wastewater or insufficient wastewater treatment, toxic chemicals from industrial and agricultural activities, and eutrophication in lakes/reservoirs (UNESCO 2006). Groundwater in Sri Lanka in all three climatic zones are under serious threat mainly due to pollution occurred through agricultural activities and over extraction that causes the declining of groundwater levels resulting in salt water intrusion particularly in the coastal belt (Panabokke and Perera, 2005). Paddy cultivation is the most widespread agricultural practice throughout the island that could seriously affect the groundwater quality due to excessive application of fertilizers (Gunatilake and Iwao,2009, 2010). Perera (2016) revealed that there is an increasing trend of soil salinity with the increase of cropping duration of Agro-well lands. This situation too can affect the groundwater quality changes in the dry zone. The link between the contamination of groundwater due to either natural or anthropogenic courses leads to many health problems and the incidence of some geographically distributed diseases and environmental factors is clearly seen in Sri Lanka (Dissanayake and Chandrajith, 1999).

2. The Study Area

Belihuloya Mini Catchment area spatially lies between 6º39" and 6º45'13''N and 80º44 and 80º49" E and comprises a total area of 42 km^2. The Belihuloya stream is one of the major tributaries of the Walawe river basin, and the mini catchment area of Belihuloya is found in the upper tributary of the Walawe River, typical of mountainous landscape. The Belihuloya tributary originates from Horton plains grassland and the study area, Belihuloya, is surrounded by Horton Plains from North, the Samanalawewa reservoir from the South, Paraviyangala peak and Hirikatuoya from East and Hagala peak from the west.

The study area comprised 7 Grama Niladari Divisions (Yakdehiwala, Belihul-oya-upper, Belihul-oya-down, Muththetuwegama, Kinchigune, Kumburuteniwala, and Karagastalawa), belonging to Imbulpe Secretariat Division, Rathnapura District in Sabaragamuwa Province in Sri Lanka.The entire Walawe river basin come under the three major agro-ecological zones, namely wet, intermediate, and dry zones. The mean annual rainfall in each zone was found as 2500 mm, 1750-2500 mm and less than 1750mm respectively. These zones are further divided in to regions based on elevation, rainfall and soils. The study area lies under IU_3b and IM_2b Agro-Ecological Zones, of Sri Lanka. The mean annual rainfall of IU_3b is > 1700mm and IM_2b is >1600mm. The study area receives precipitation mainly from the Northeast Monsoon and Inter-Monsoons. It receives high intensity of rainfall from late December to late April, and average day temperature is between 22-25ºC. Between December and March, night temperature goes down to 15ºC. Between August and October (dry period) day temperature goes up to 30º C and night temperature varies around 20º C (Francois Molle.,*et al.* 2003).

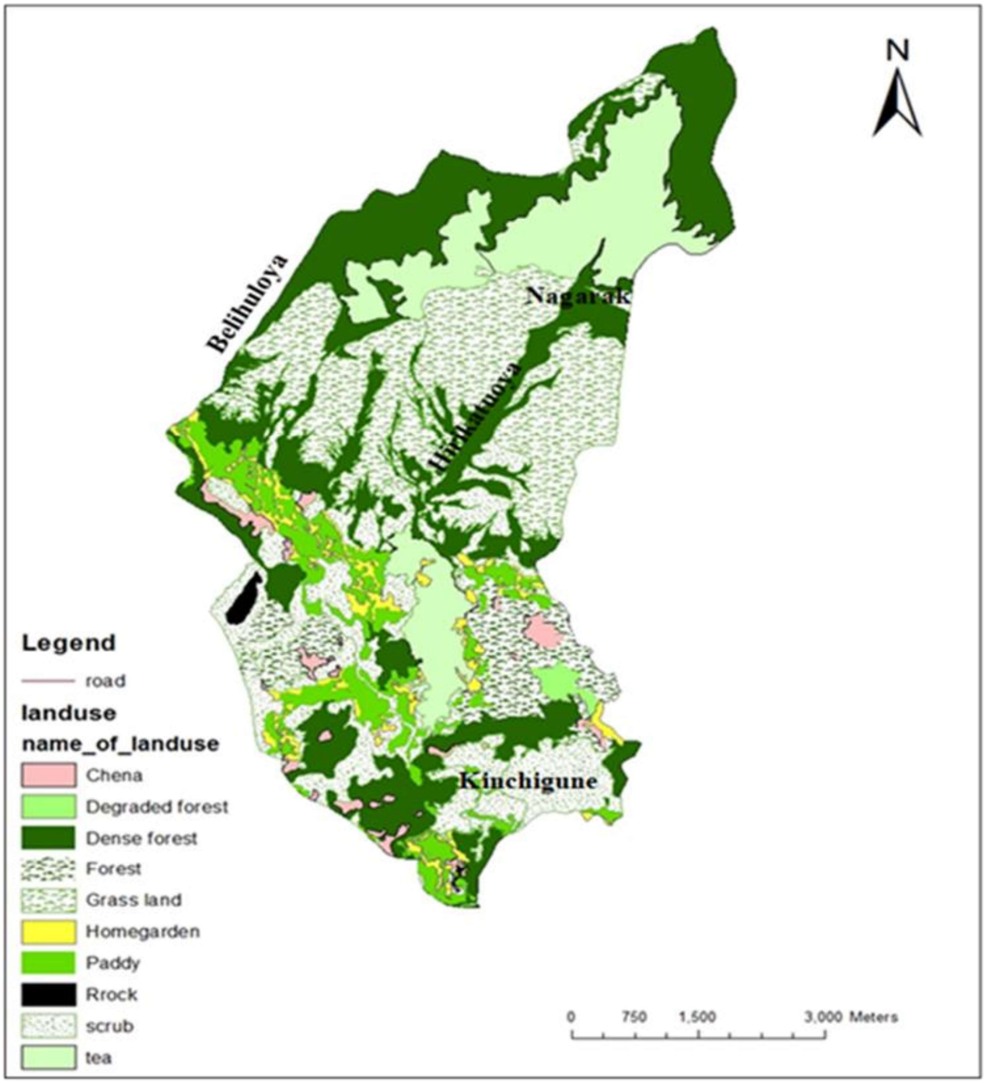

Figure1: Study Area

According to the general soil map of the country, upper-catchment of the study area is covered by Red Yellow Podzolic Soils (RYPs) and Wet Mountain Regosols, while the lower catchments of the study area comprise Red Yellow Podzolic Soils RYPs. Red Yellow Podzolic Soils (RYPs) are grey to dark brown in colour with sandy clay loam texture. The pH varies from 4.5-5.5. Sub soils are brown to yellowish brown or yellowish red in colour, sandy clay loam to clay loam in texture and pH 4.0 to 5.5. These soils have a low erodibility factor, but lend to erosion when they occur on steep slope exposed to heavy rainfall and have undergone erosion and show no recognizable horizons other than a weakly developed A1 horizon. They are similar in colour and texture to the RYPs (CEB, 1992).

3. Materials and Methods

In order to investigate special variations of water quality parameters in the groundwater of the area, water samples were collected randomly in irregular intervals (during 1st Inter Monsoonal and North Eastern Monsoonal period) in 2016. 20 water samples were selected containing 10 samples from springs, and 10 samples from wells in the selected area. Water samples were collected in pre-cleaned polyethylene containers. In the field, containers were further rinsed with the water to be sampled prior to the collection. Two unfiltered samples were collected at each site and were tightly sealed.

Careful attention was paid while collecting water samples to avoid the trapping of air bubbles. pH, water temperature and electrical conductivity (EC) were measured in-situ. Samples were preserved according to the standard methods approved by The United States Environmental Protection Agency (US-EPA). The collected samples were kept cool (~ 4 ºC) and transported to the laboratory of Department Geology, Faculty of Science, University of Peradeniya, where all chemical parameters were measured. The chemical parameters were measured within the recommended time periods.

The pH, and electrical conductivity (EC) were measured in the field using electrochemical methods. Titrimetric methods were used to determine the concentrations of chloride. HACH® digital titrator was used for all titrations. The anionic parameters Nitrate-N (NO3-–N), and sulphate (SO4-2) content was analysed using spectrophotometric methods. HACH® DR-2400 and HACH® DR-2800 spectrophotometers and HACH® pre-prepared chemicals were used for the determination of the above parameters.

Spectrophotometers were calibrated using appropriate standard solutions prior to the analysis. The cations, sodium (Na+), potassium (K+), and calcium (Ca+2), were analysed using Atomic Absorption Spectrophotometric (AAS) methods (Perking Elmer- 2800). Standard analytical procedures were adopted for water analysis as recommended by APHA (1995) and Hach® (2002).

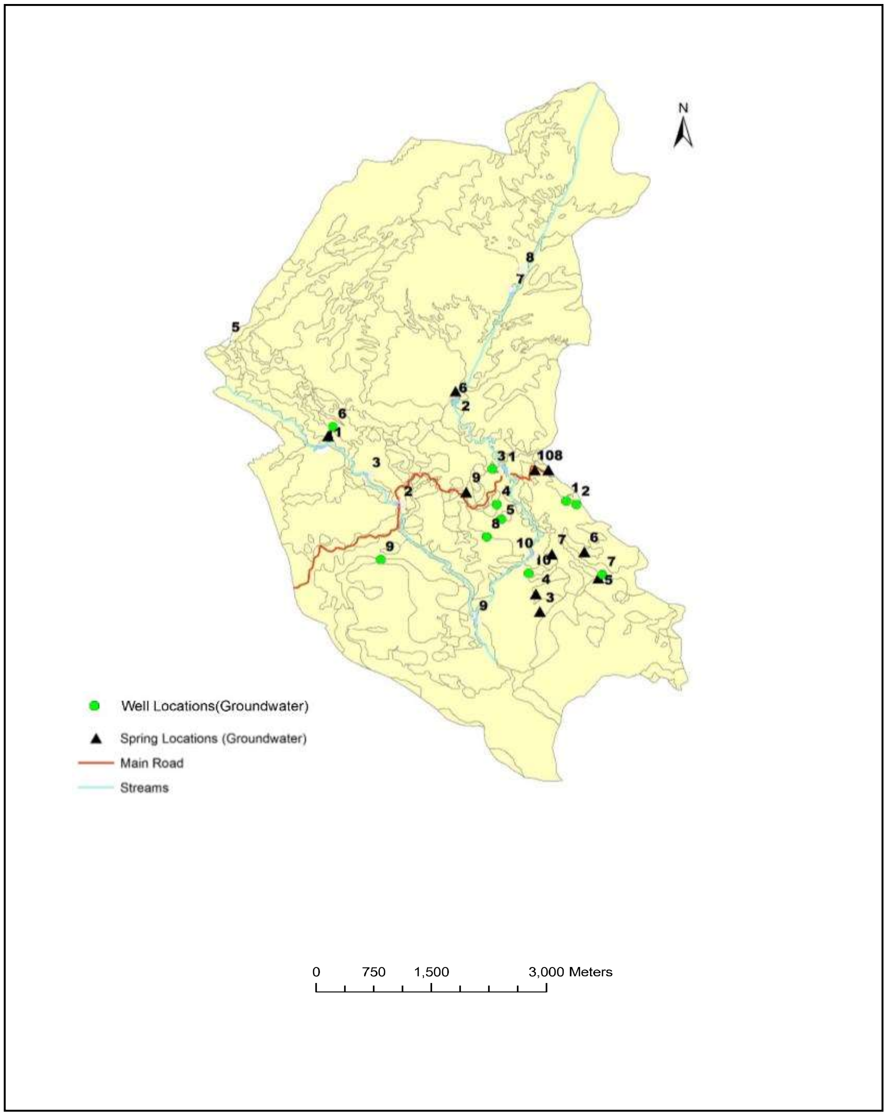

Figure 2**:** Locations of well and spring water samples obtained in the study area

The pH, and electrical conductivity (EC) were measured using a Sension+ MM150 Portable Multi Meter for pH, and Conductivity field kit. The Na2EDTA (Disodium dihydrogen ethylenediamine tetraacetate) titration method was used to determine the hardness of the water samples. The cadmium reduction method with the measuring ranges of 0.1- 10.0 mg/L NO3-- N was used to measure the nitrate content of water. Sulphate content was measured using the barium sulphate method which is sensitive from 2 to 70 mg/L SO4-2. Finally, The Chloride content of the water was analysed by the silver nitrate titration method.

The thematic maps like Base map, Drainage map, Land use/ Land cover map were generated from USGS Earth Explorer and Google-earth satellite image of 2016.The preparation of the contour maps was obtained by ArcGIS Ver. 10.3. Inverse distance weighting method was used for contouring.

4. Results and Discussions.

Water quality Variation of Groundwater in Belihuloya Mini-catchment area

Due to RYP sub soils prevailing in the area, all well water showed a low pH (4.5-5.5 and 6.2-6.6) in the area. Spring water also showed pH level values between 6.4-6.8 and 7.2-7.4. However, spatial variation of NO_3, SO_4, EC, Na, Cl, and K, in ground water (well water, and spring water) showed similar variation parallel to land use categories of forest, paddy, home garden, tea, grass lands, and scrub lands, in NEM[22] and 1st IM[23] periods in the study area. From them, pH in ground water (wells) were not found under WHO standards in the area. Spatial variation of Ca concentrations in well water (Ca;10.37-24 Mg/l) and Ca concentrations in spring water (springs; 2.8-3.4 Mg/l,) were higher along lower and middle catchment area.

pH is the most common measurement of the acidity balance in a solution (Younger, 2002). According to the observations, low pH concentrations in wells were found in the Western part of the mini-catchment area and high levels were observed in its Eastern part. According to Figure 3 (a), some wells located in build-up area shows the highest value of pH (6.6) in the drinking water, while the water from other wells show a pH level ranging from 5.07 to 6.22 in the study area.

Concentrations of pH of the springs in the area varies from 6.48-7.42 during the first Inter-Monsoon period in the area (Figure 3, b) Most of the springs observed were below 7 values and were under WHO guidelines of drinking water. Highest concentrations of pH were observed particularly in the springs located in down catchments (South eastern part), Western part and Eastern part in the middle catchments. The high pH levels in spring water reflects its natural source in the carbonate dominated geological background in the area.

Concentration of Nitrate (NO_3) in the study area ranged from 0 to 3 mg/L and distribution spatially varied differently under specific land use in the area, and highest concentrations were found in the middle-catchments in the study area (Figure3). Highest concentration of NO_3 was found in wells (Figure3: c),

[22] North Eastern Monsoonal Period
[23] 1st Inter Monsoonal Period

where the relevant land use is predominantly paddy cultivation and built- up areas.

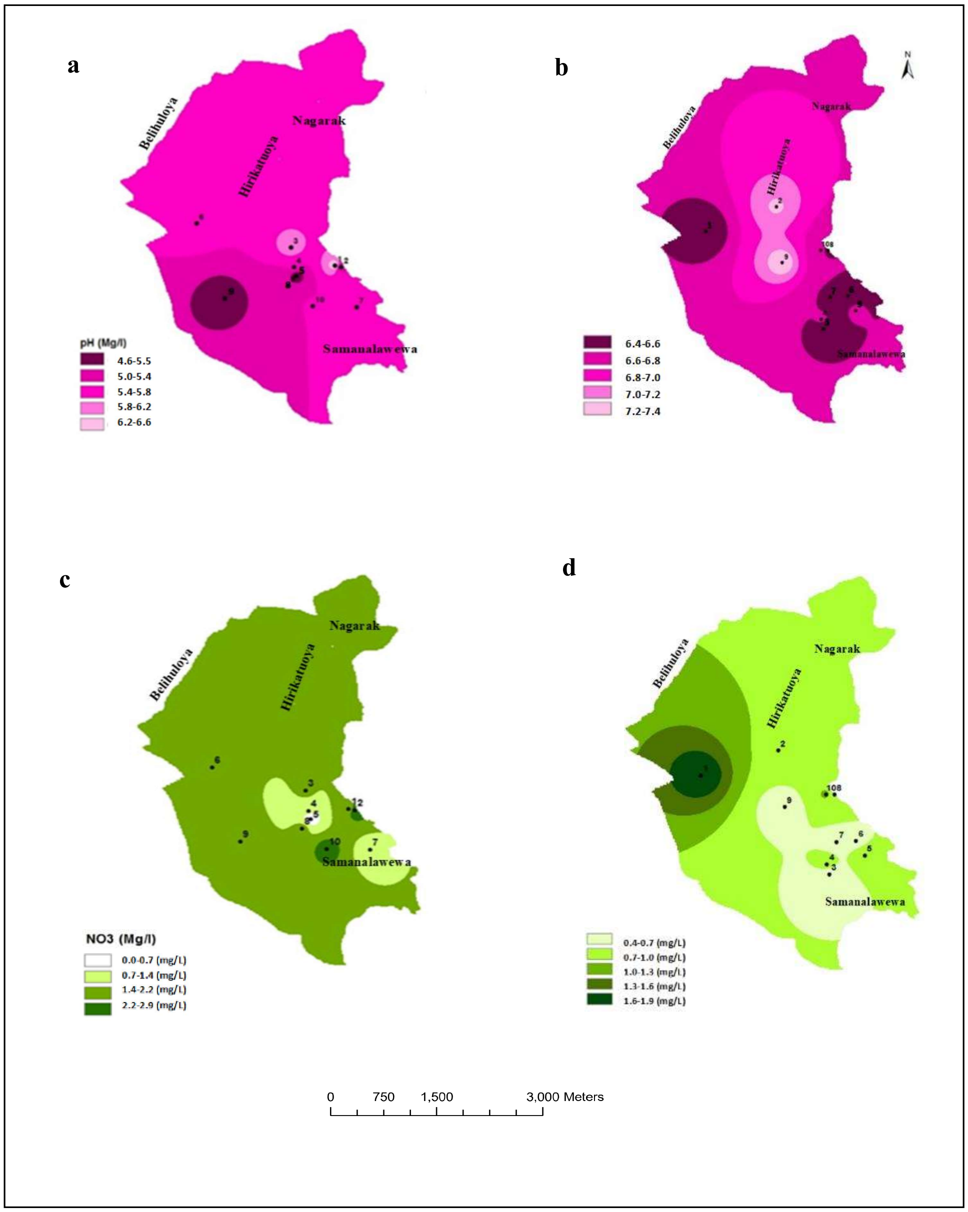

Figure 3: Spatial variation of pH and NO_3 in well and spring water in the study area**: a;** Spatial variation of pH in wells **b;** Spatial variation of pH in springs **c;** Spatial variation of NO_3 in Wells **d;** Spatial variation of NO_3 in springs

These concentrations found are due to the fact that the nitrate loading is usually highest with paddy fertilizing season following North Eastern Monsoon in the area. Concentrations of (NO_3) found in the springs vary from 0.4-2.0 mg/L during the first Inter-Monsoon period in the area. According to

Figure 3: d, highest concentrations were observed at the springs (2.0 and 1.1 mg/L) associated with paddy cultivation, and home gardens in the area and similar locations where NO_3 concentrated in well water in the area, also highest concentrations of NO_3 was observed particularly in the western part, in the middle and the upper catchments associated with paddy and tea in the area.

Concentration of EC (Electric Conductivity) in the wells (Figure 4: a) ranged from 0-71 µm/cm in the area. Highest concentration was observed in the Eastern part of the mini-catchment area where the wells were located in middle parts especially in the built-up area. Deforestation with expansion of buildings in the specific areas have uncovered the water sources and increased water temperature levels have increased the EC levels in the wells in the study area. Spatial variation of the EC values in the wells were observed as similar to the spatial variation SO_4, Na, and Cl concentrations in the Belihuloya. However most of the wells observed were under WHO levels in the area.

EC in springs vary from 7-158 µms/cm in the area. Highest EC values were observed in the springs (158 and 49.8 µms/cm) associated with scrub land and paddy in the study area. Highest concentrations were observed in the springs located in down catchments while less values were observed in the Western part of upper catchments in the study area (Figure 4: b). Spatial variation of both EC, Na and Cl values observed in the springs are similar in the area where usually highly soluble minerals such as halite are developed by EC in the environment.

Chloride (Cl) concentrations in the study area varies from 2.9-16.3 mg/L during the North Eastern Monsoon period in the area and the highest amounts were observed at the wells (11 and 16.3 mg/L) associated with paddy and home-gardens in Belihuloya (Figure 4: c). Cl concentrations in the well water was found to be similar to the spatial variations of SO_4, EC, and Na concentrations in the Belihuloya. Cl in the springs (Figure 4: d) varies from 3.7-12.5 mg/L in the area. All Chloride values were under permissible levels of WHO guidelines in the area. Chloride (Cl) is a widely distributed element in all types of rocks in one or the other form and its affinity towards Sodium (Na) is high.

According to Figure 4: d, highest Cl concentrated springs were located along the down catchments associated with built-up area and home gardens, and spatial variation of Chloride concentrations in the springs were similar to the variations where Sodium (Na) concentrations were high in the springs of the study area.

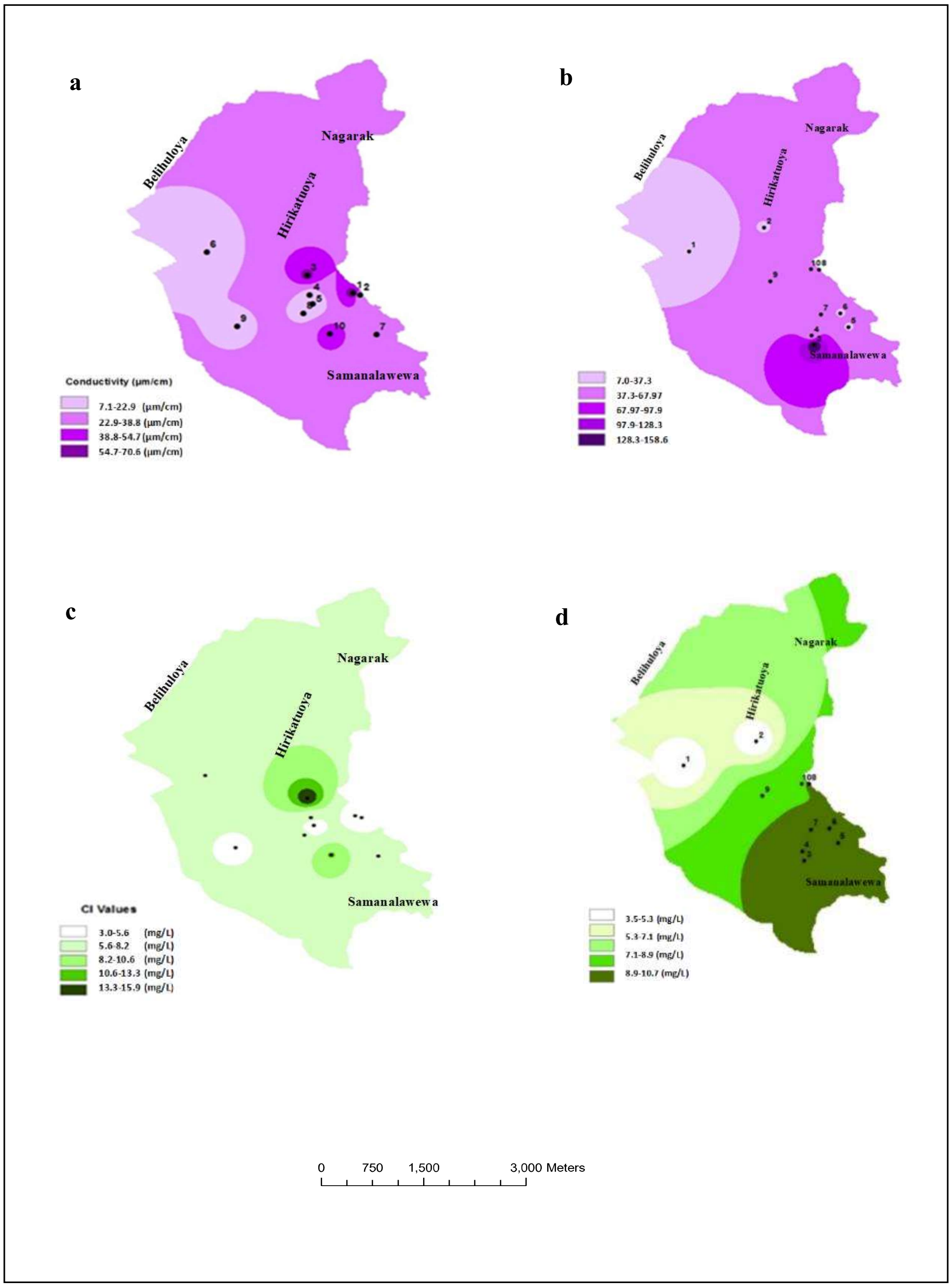

Figure 4: Spatial variation of EC and Cl in well and spring water in the study area**: a;** Spatial variation of EC in wells **b;** Spatial variation of EC in springs **c;** Spatial variation of Cl in Wells **d;** Spatial variation of Cl in springs

Concentrations, of Sulphate (SO_4) in the well water varies from 1to 5 mg/L in North East Monsoon period in the area, and high concentrations was observed in the middle catchment (4mg/L and 5mg/L) wells, associated with paddy, home-gardens, and built-up areas in Belihuloya (Figure 5: a), while lower levels were observed at the western part of the catchments, and all observed values were under the WHO guidelines in the area. However, spatial variation of the SO_4

concentrations in the wells were similar to the EC, Na, and Cl concentrations in the study area.

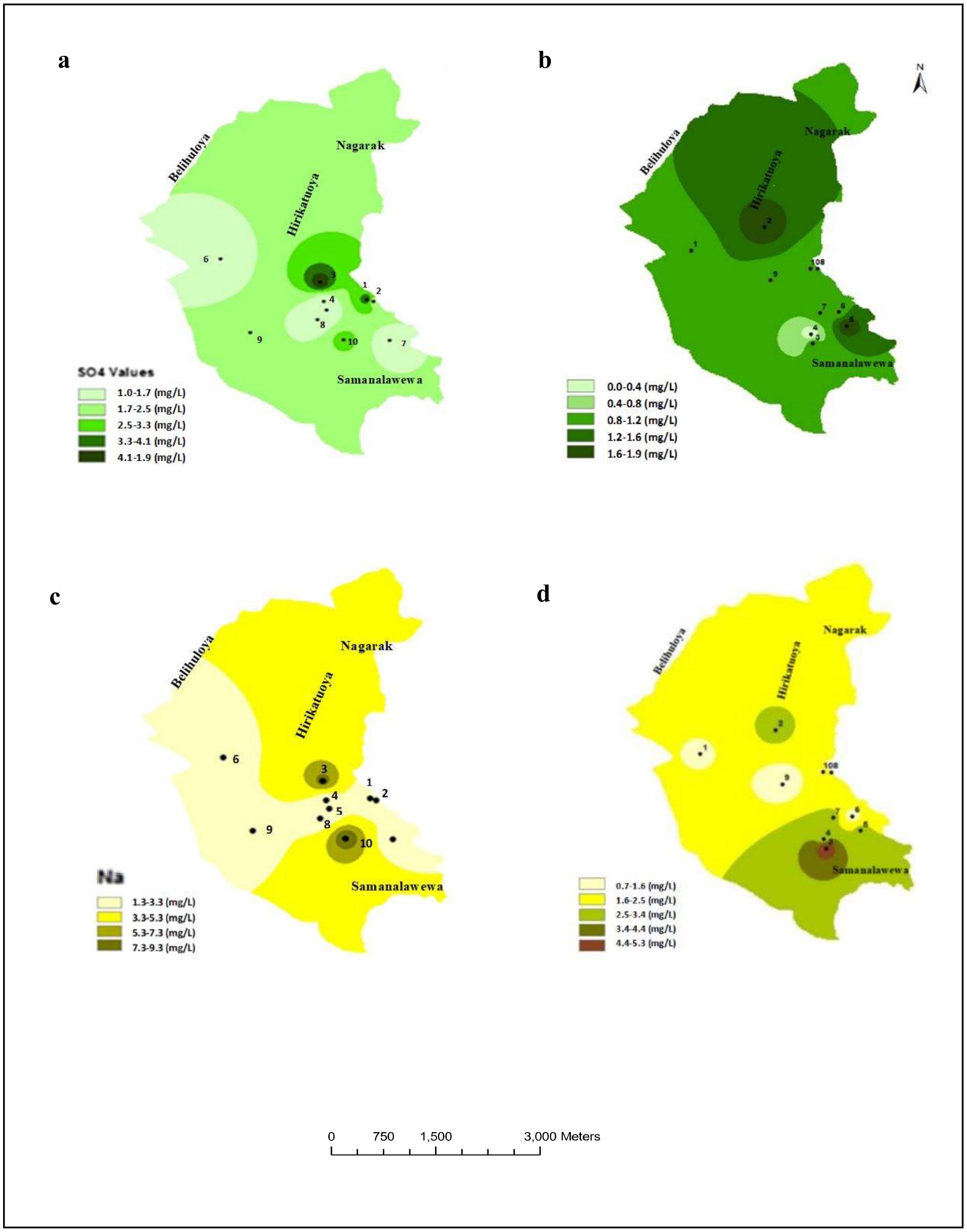

Figure 5: Spatial variation of SO_4 and Na in well and spring water in the study area**: a;** Spatial variation of SO_4 in wells **b;** Spatial variation of SO_4 in springs **c;** Spatial variation of Na in Wells **d;** Spatial variation of Na in springs

(SO4) concentrations in the spring water varies from 0.0-2.0 Mg/L in the area, also detected under WHO guidelines. However, highest concentrations of SO_4 was observed mainly in the upper catchments associated with pines and tea cultivations and Eastern part of the down catchments accompanying built-up area and the home gardens in the study area.

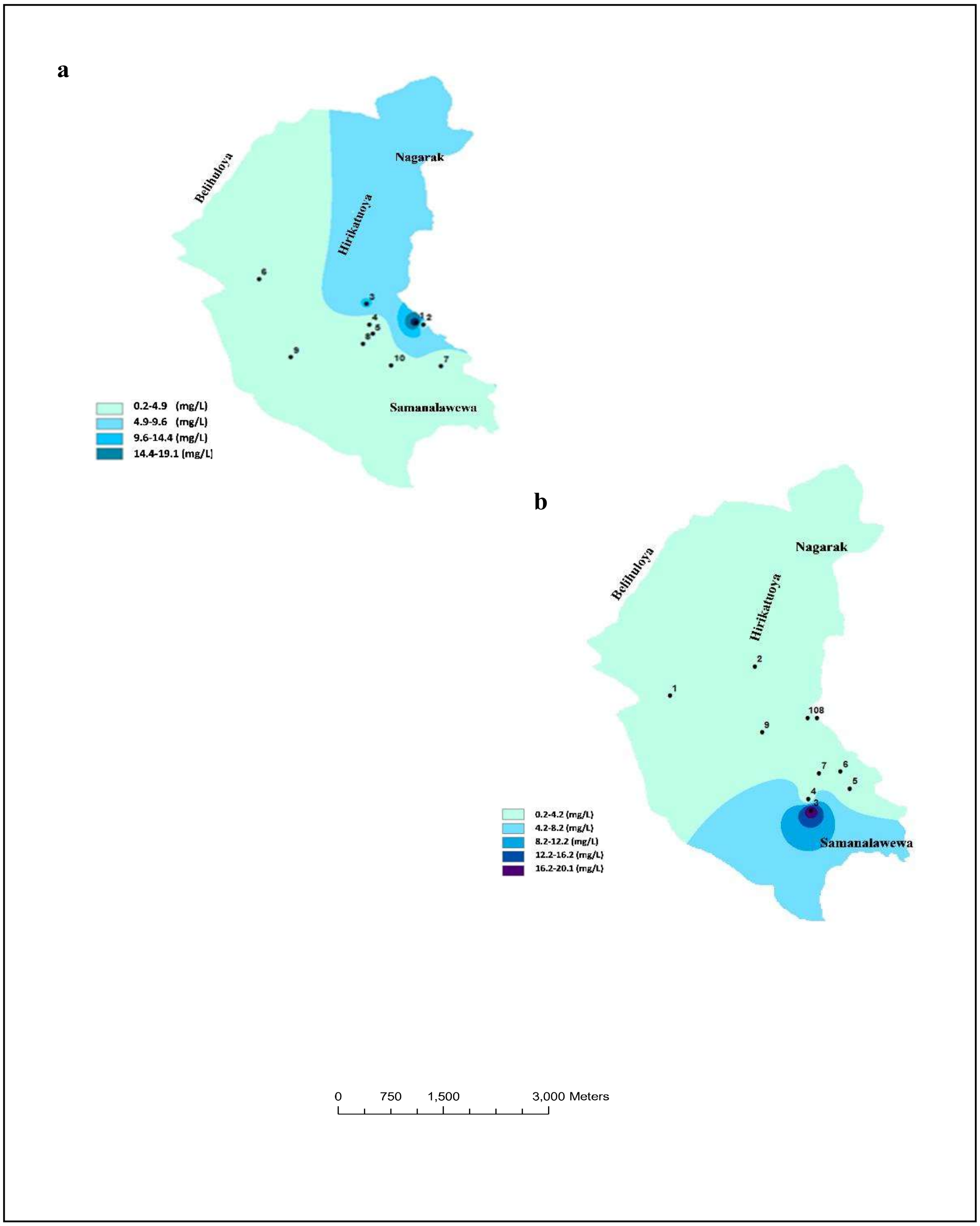

Figure 6: Spatial variation of Ca in well and spring water in the study area**: a;** Spatial variation of Ca in wells **b;** Spatial variation of Ca in springs

Sodium (Na) among the Alkalis is the predominant chemical constitutes of the natural water. Sodium (Na) varies from 1.875-9.34 mg/L in the area. According to Figure 5: a, highest concentration of Na was observed in the middle catchments particular in the Eastern part where the wells are associated with heavy paddy cultivation in the area. Na concentrations in the springs vary from 0.75-5.332 mg/L in the area, where highest concentrations were observed particularly at the springs (5.33mg/L and 3.01 mg/L) associated with home gardens and scrub lands in the area (Figure 5: b). Spatial variation of highest Na concentrated springs was detected in lower catchments and middle catchments, associated with built-up area and home-gardens. Spatial variation of Sodium (Na) concentrations in springs were detected in the area displayed similar variation with K, EC, and Cl, in springs respectively.

Calcium (Ca) is a common and widespread element and it is distributed widely in soils and rocks (Mohan et al, 2000). Ca concentration varies from 0.2-24.02 mg/L in the area. The highest Ca concentration was marked in the well (24.02mg/L) located in the middle catchments, probably in the built-up area and all detected Ca values were under the WHO standards in the area. Calcium is predominantly sourced from dissolution of carbonate minerals, especially calcite. According to Figure:6 a, highest concentration of Ca was observed in the wells located in the eastern part of the catchment area associated with Hirikatu-oya mini stream.

Ca is one of the Alkaline earth metals widely distributed in earth crust and present abundantly as a cation in ground water. Spatial variation of Ca concentrations of a specific location of the springs vary from 0.26-20.2 mg/L in the area, where highest recorded in spring (20.2mg/L) similar to Na, EC concentrations of the springs in the area. According to Figure: 6 b, high concentrations of Ca in springs were detected in lower catchments parallel to Chloride, EC and Na concentrations, associated built-up area and home-gardens in the area. Higher concentrations of Ca observed were in springs along lower catchments where, Samanalawewa Project is located and geologically the area of karst within the Highland series of the Sri Lankan Precambrian complex comprised of crystalline metamorphic rocks (K. Laksiri et al,)

5. Conclusions

According to the present study of the Hydro-geochemical variations of groundwater in different land use types have taken place in the last few decades in the Belihuloya Mini-catchment area. This study attempted to find water quality changes in different land use changes in Belihuloya during 2015 to 2016. Since the time farmers had adopted HYV for paddy, utilization of water for farming in the area increased while farmers were attempting to cultivate two times per year using ani-cuts in the area. The study of water quality has shown the spatial variation of pH, and Ca, in groundwater (well water and spring water) and natural reasons for changes were explained. However, spatial variation of NO_3, SO_4, EC, Na, and Cl, in groundwater have shown similar variations parallel to land use categories of forest, paddy, home garden, tea, grasslands, and scrublands.

The spatial distribution pattern of water quality parameters in groundwater revealed the cause and effects of utilization of fertilizer in the area. NO_3, SO_4, Cl, EC, and Na, in groundwater (wells and springs) were observed in higher levels along paddy cultivation, home gardens, tea lands and built-up areas, particularly in the middle catchments where earliest land use type was the forest in Belihuloya. However, results harness the introduction of HYV [24] for both paddy and tea tend to utilize chemical fertilizers, weedicides, and pesticides for farming activities. Thus, people strongly believed that water quality of streams and wells deteriorated due to the application of chemical fertilizers, weedicides, and pesticides of agricultural practices and further increased sedimentation in the streams.

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